R E P O R T R E S U M E S

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PLUMBING FIXTURE REQUIREMENTS IN UNIVERSITY INSTRUCTIONAL AND RESEARCH BUILDINGS.

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EDUCATIONAL FACILITIES LABS. INC., NEW YORK, N.Y.

PUB DATE NOV 61

EDRS PRICE MF-$0.25 HC-$1.04 24P.

DESCRIPTORS- *COLLEGE BUILDINGS, *COLLEGE PLANNING, *FACILITY GUIDELINES, *PLUMBING, DATA COLLECTION, DATA SHEETS, EQUIPMENT, SURVEYS

A METHOD FOR DETERMINING THE NUMBER OF TOILET FIXTURES REQUIRED IN COLLEGE BUILDINGS WAS DEVELOPED FROM ESTIMATING THE MALE AND FEMALE POPULATIONS AND FROM OBSERVING AND RECORDING THE FREQUENCY AND DURATION OF FIXTURE USE AND WAITING TIME. CHARTS INDICATING THE RECOMMENDED NUMBER OF URINALS, LAVATORIES AND WATER CLOSETS, WHICH CONSIDER THE POPULATIONS AND USAGE RATES ARE INCLUDED. THE APPENDIX CONTAINS THE DATA SHEETS FOR COLLECTING THE INFORMATION OF FREQUENCY OF USE. (HH)

ED0141197

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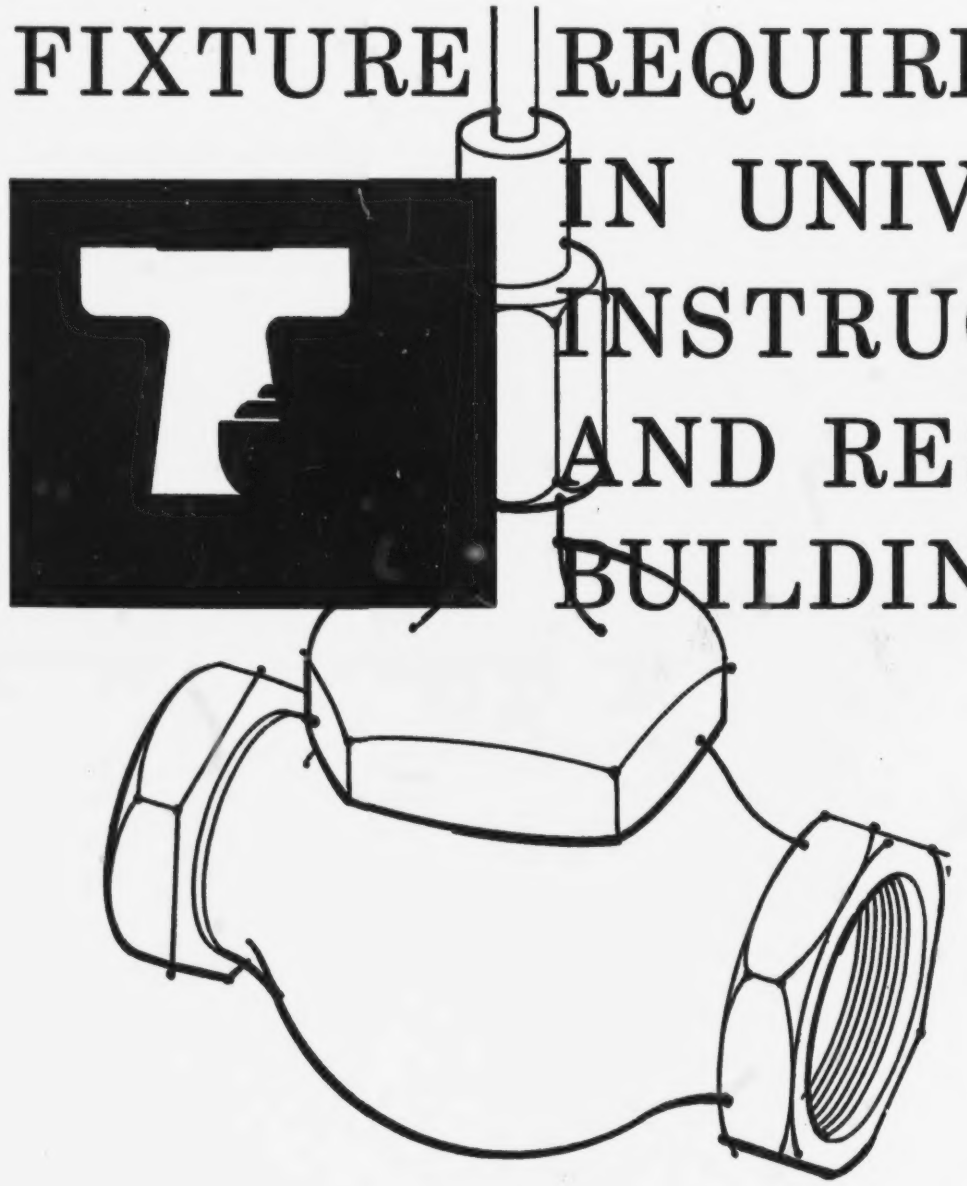

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Committee on Institutional Cooperation 20
University Facilities Research Center
Educational Facilities Laboratories, Inc.

Library of Congress Catalog Card No. 61-18843

Third Printing
November 1964

The Background

Unprecedented enrollment increases in American colleges and universities are with us and ahead of us. These same institutions are greatly expanding their activities in the fields of research and service to the public. All of this adds up to the creation of a need for new building facilities in a magnitude never before experienced.

The University Facilities Research Center has recently completed a building survey while studying immediate needs for instructional, research, operating and housing construction at the large middlewestern universities comprising the Council of Ten and the University of Chicago. This survey covered the period from the end of World War II through the ten year forward planning time adopted by the eleven universities. It indicated that approximately $1.85 billions in construction could be expected between 1946 and 1970. Of this about $1.1 billion in construction, or 60%, is now being planned or built or projected for the near future. On a national scale, this would indicate college and university building programs amounting to something in the order of $15 billion between now and the end of this decade.

Among the objectives of the Research Center is the isolation of planning and design criteria problems, followed by the finding or developing of measures for design—all to the end of permitting the best possible use of the university and college construction dollar. Analysis of statistics and interviews and conferences with interested people in the field have contributed to the selection of several monograph subjects, of which this publication is one.

The material is aimed at aiding university and college administrators and their planning and building committee people. It is also directed at private architect and engineer firms engaged in the design and execution of new facilities.

Madison, Wisconsin, October, 1961

Plumbing Fixture Requirements in University Instructional and Research Buildings was selected as a subject for study because plumbing installations represent a significant cost item for modern building construction, and it was felt that here should be a place where appreciable savings might be realized while preserving proper standards of performance and public health. It seemed that campus buildings present some unique characteristics of occupancy, and that by having these buildings designed in accordance with usual code and custom, they are probably overfixtured. Preliminary study of building and plumbing codes which set the trend for fixture selection indicated that the codes, for the most part, did not seem to consider the college and university building as a building type apart from primary, intermediate and secondary educational buildings. The question then became: are college and university buildings, in fact, overfixtured? If so, by how much? How should proper fixture design be accomplished? What range of savings in construction costs is involved here?

To find the answers to these questions, and to put the findings into a form of value in pursuing the planning and designing of future college and university buildings, the Research Center engaged the services of Taylor, Lieberfeld and Heldman, Inc. of New York, Consultants in Space Utilization, Building Programs, Management Controls. This organization has had considerable recent experience in the college and university field; it was selected because of this background.

The body of this monograph, its findings and its recommendations are very largely the work of the Consultants.

W. S. Kinne Jr.

Director, University Facilities Research Center

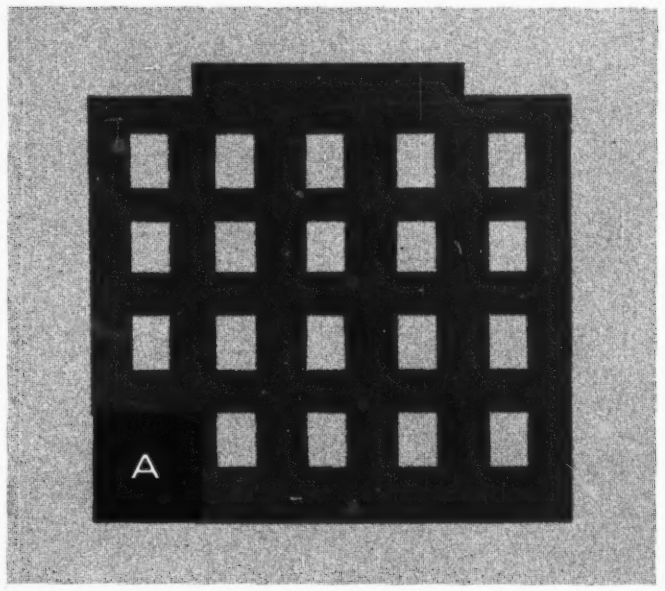
PLUMBING FIXTURE REQUIREMENTS IN UNIVERSITY INSTRUCTIONAL AND RESEARCH BUILDINGS

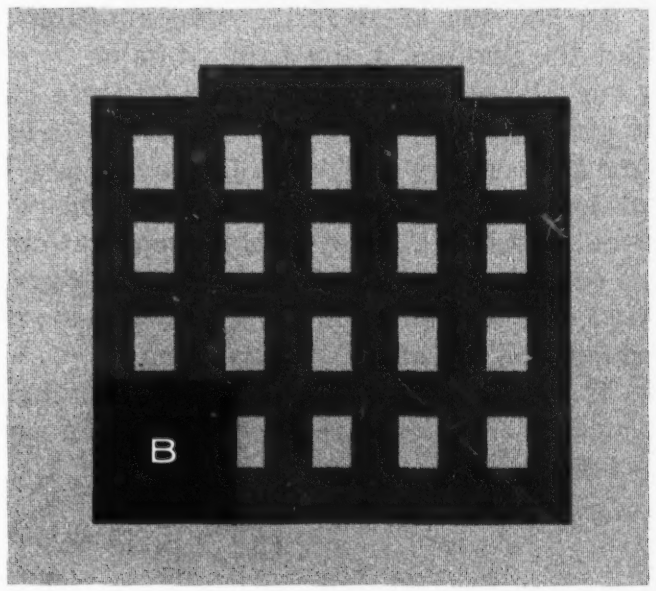
I. *Preliminary Considerations*

A. Scope

The programming of toilet fixtures is a largely undeveloped area in the planning of college and university buildings. Knowledge concerning the frequency of use of these facilities is fragmentary. As a result, installations with too few or too many fixtures are common.

The object of this monograph is to develop a system for estimating the number of fixtures of each type required in college buildings. The study is limited to the principal fixture type, that is, water closets, urinals and lavatories for men and water closets and lavatories for women. Only fixtures located in toilet rooms will be investigated, as opposed, for example, to sinks in laboratories. Under study are buildings for teaching and research, including office, classroom and laboratory space. Dormitories, libraries, student centers and so forth are outside the scope of this report.





B. The Case

Plumbing fixtures and toilet rooms are worth analyzing systematically because, although they occupy only about two and one-half percent of the net area of college buildings, they represent an investment out of proportion to the space they require.

Facilities such as these in institutional buildings must be designed for long life, easy maintenance and sanitary qualities. This implies tile floor and walls, marble or other high grade toilet stalls, and first quality fixtures, fittings and piping. The result is that the toilet room is perhaps the most expensive area in the building on a unit cost basis. The total cost is closely, though not exactly proportionate to the number of fixtures. Section IV contains specific information on costs.

The number of plumbing fixtures of each type which are required are, in most cases, specified by the building code controlling construction practice in the particular locality. Only a few such codes have special prescriptions for university buildings. Where the code does not refer to buildings for higher education, the university may be able to work out some special arrangement to suit its own requirements, or it may be forced to accept regulations applying to all buildings without distinction as to function. In a number of cases the regulations designed for primary and secondary schools may be mandatory for colleges as well.

The result of this confused and unsatisfactory situation is the development in the minds of a number of college administrators of the thought that much money has often been diverted to toilets that could have been more usefully spent on classroom, office or laboratory space. It is a known fact that most plumbing installations for modern campus buildings being built today will cost from 3.5 to 12 percent of the total construction outlay. Therefore, an analysis which aids in pinpointing the minimum number of fixtures required for the reasonable convenience of the user has practical utility.

C. Method

There are two facets to programming plumbing fixtures:

1. The population of the building must be estimated. This is relatively simple in office and research area but presents problems in scheduled space, classrooms and teaching laboratories, where population may change from hour to hour, from day to day and from year to year.

2. The number of fixtures of each type required must be related to the building population; requirements for males and females must be estimated separately. The determination of the ratio of fixtures to occupants can in turn be approached in two ways:

   a. The users of the fixtures can be questioned (either by interview or questionnaire) with a view to ascertaining the frequency and duration of use in various circumstances.

   b. The toilet rooms may be monitored to record the characteristics of actual fixture use. The data gathered in this way can then be related to the size and composition of the population in a specific building and floor at a particular point of time.

A technique for approaching the problem through data supplied by the user has been developed in model form at Purdue University.[a] The only potential difficulty in applying this method on a broader scale is the comparatively cumbersome process of soliciting information from a large group of students. However, if the procedures described in the Purdue study were actually carried out more widely, the results would undoubtedly be very valuable.

The Consultants have used the second of the two approaches outlined above, partly because the first had already been developed by others and partly because, while promising equally useful results, the second seemed simpler to employ. The principal steps of this survey are described below.

1. The population present at a particular time in a college building is counted. The number of males and females are recorded separately. In classroom buildings this procedure is repeated at each hour. In general the survey covered the hours from 9 AM through lunch.

2. An observer is stationed in each toilet room continuously for this period of time. This person records the number of times each fixture is used, the duration of each instance of use and the number of persons, if any, waiting for each type of fixture.

This survey technique will work only under certain conditions. For example, if a toilet room is known to be crowded, with unpleasantly long waiting periods resulting, then potential users will be discouraged and seek other facilities. Thus, the activities observed in the room will not serve as a true guide to demand.

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[a] Purdue University Statistical Laboratory. **A Sample Survey Design Using the Operations Research Queuing Theory for Establishing Plumbing Fixture Requirements,** 1954 (unpublished)

However, if there are more fixtures in the toilet room than the population using the room actually requires, then the observations will indicate a ratio of fixtures to population which will demonstrate actual demand. The Consultants attempted to find installations which served considerable numbers of persons, yet were under-utilized. In practice this is not difficult, for the effect of most codes is to require an overabundance of fixtures. In addition, the college may have felt that, in the absence of reliable guides, too many fixtures were better than too few, so that oversupply is thus made even more common.

The principal form used in the survey, with corresponding instruction sheet, is reproduced in the Appendix.

Surveys based on field data have been used before in studies of primary and secondary school toilet requirements, most notably in a study prepared at Stanford for the Plumbing Fixture Manufacturers' Association.[a]

The present effort, oriented solely towards colleges and universities, must be considered as a pilot study. The surveys undertaken are not sufficiently numerous to provide definitive results, although their implications seem consistent with a trend on the part of college administrators to reduce fixture-occupant ratios. It is hoped that a number of institutions will gather additional data from their own practice, which will then serve to confirm or revise the findings of this monograph.

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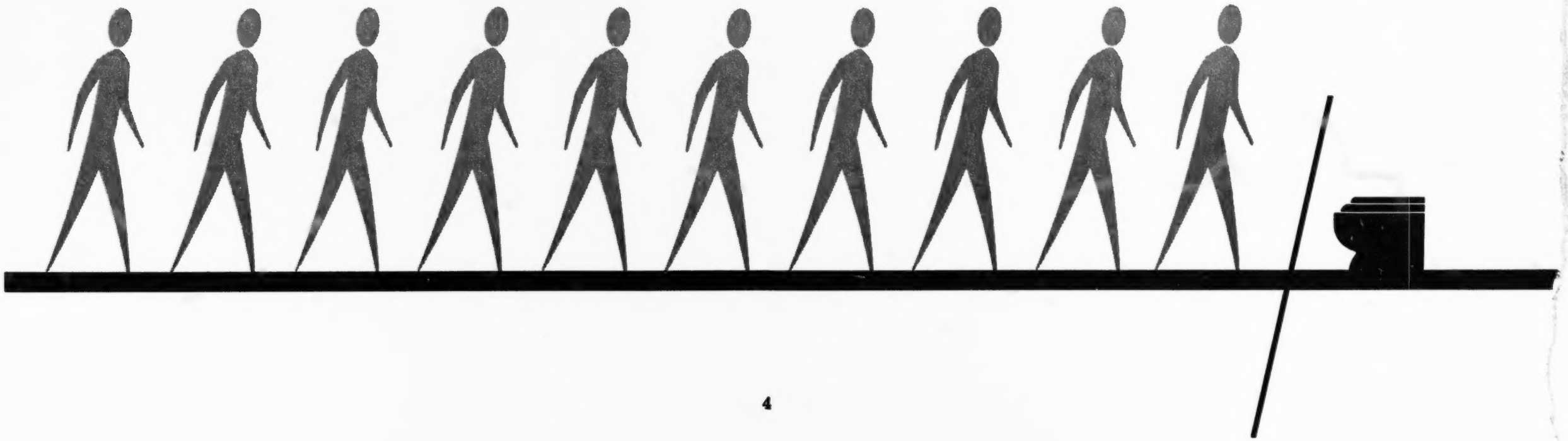
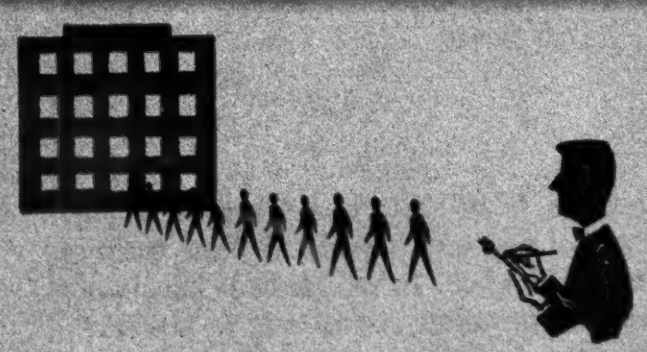
[a]School Planning Laboratory, School of Education, Stanford University. **Plumbing Fixtures for Education Facilities**, Stanford, California, 1959





II. *Building Population*

A. Classrooms and Teaching Laboratories

The first task in developing a method for estimating plumbing fixture requirements is to define the number of occupants. It is unrealistic to equate this figure with the number of available seats, whether fixed or movable. To establish a means of estimating the population of classrooms, three measures of utilization must be used:

1. Room utilization refers to the percentage of available classrooms in use at a particular hour of the day or throughout the teaching week.
2. Student station utilization refers to the percentage of seats filled at the hours the classrooms are scheduled.
3. Capacity utilization refers to the product of the percentages of room and student station utilization.

Various studies made in the past five years indicate that room utilization averages only about 50 percent of a 44-hour week. Student station utilization is not much higher and the product of the two probably averages around 30 percent. However, there is evidence that these figures are rising and that effective pressures for more intensive use of space are currently operative. An average of 80 percent room utilization and 70 percent station utilization would represent a goal desired by many but achieved by only a very few institutions today.

Because of the often uneven distribution of classes through the teaching week, dealing with average or even projected average utilization figures may result in understanding requirements. Therefore, provision should be made for the population at peak periods. The factors suggested are 90 percent for room utilization and 75 percent for student station utilization. It is felt that utilization rates more intensive than these will occur so rarely that planning for them would be inefficient and uneconomical.

The capacity utilization which is the product of these two percentages may be rounded to two-thirds of full capacity of the total student stations available.

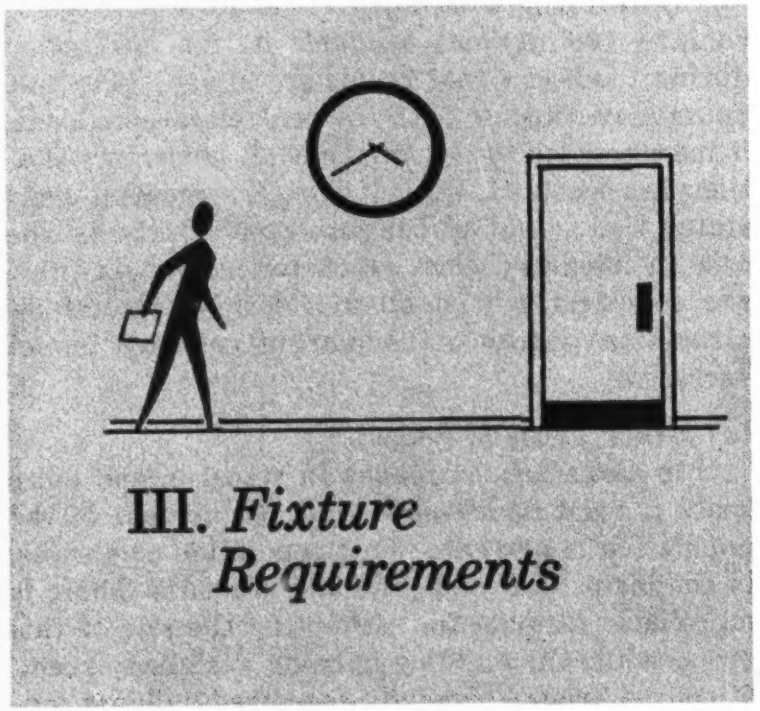
Thus, in programming toilet fixtures, it is recommended that population in classrooms be considered as two-thirds of station capacity.

In teaching laboratories it is quite possible to achieve 100 percent student station utilization during the hours that rooms are in use. As these hours may coincide with the peak classroom loads, it may be wise to assume that all laboratory stations are occupied. This, of course, somewhat overstates the actual utilization, particularly in the case of advanced class laboratories, but as these are comparatively small in relation to total instructional stations, the margin provided is not excessive.

B. Other Types of Space

In assessing occupancy in research and office space it must be assumed that 100 percent of the population is present. This population comprises, in the main, staff and graduate students. There is no reliable formula for estimating the size of this group while the building is being designed except, of course, from a carefully conceived building pro-

gram. Research space per occupant (including faculty, students, professional and non-professional staff) may vary from 100 to 400 square feet, depending on the nature of the research project and its equipment, as well as on the intensity of use. Office space varies from 50 to 200 or more square feet per person. The usual pattern is for the space per occupant in a particular building to decrease from year to year. At the time of construction there is, hopefully, room for more expansion of personnel and equipment. As time goes on this margin is absorbed. In estimating occupancy for the planning of toilet fixtures is is obviously desirable to provide for even more intensive use of space than is foreseen in the building program. Overcrowding may well become a characteristic feature of buildings of these types, but there is no way to quantify it.



III. *Fixture Requirements*

A. Classroom Buildings

The field survey provides data indicating the number of users of each type of fixture and the average length of time an individual requires for each instance of use. To convert this data to an optimum ration of fixtures : population, two other factors must be known:

1. The distribution of users in time over the ten-minute interval between classes.

2. The maximum allowable waiting time.

These factors will be analyzed in relation to particular fixture types in the discussion which follows. In general it may be said that the users may be distributed in time evenly throughout the ten-minute interval or may be concentrated within any segment of that interval. If the former, then either the number of fixtures or the waiting time can be minimized. If the latter, then either more

fixtures will be required or, for a given number of fixtures, longer waiting periods will be necessary.

The maximum allowable waiting time is not easily established. Although ten minutes are available between classes, the student will require part of that time, in many instances, to travel to the next class. In addition he may have other objectives to fulfill in relation to his academic or extracurricular activities within this limited interval. Furthermore, waiting in a toilet room is unpleasant and annoying, reinforcing the desirability of reducing the waiting time. The tables included in this section, which detail the users of fixtures as a percentage of population, are limited to the ten-minute class break interval. Although there was some toilet use during the class session, the peak loads are between classes and it is the activities taking place during this interval which must form the basis of a planning standard.

1. Urinals[a]

As shown in Table 1, urinals were used between classes by 8.5 percent of the male population constituting the sample. However, at noon the percentage was 9.3, higher than at any other hour. The population at each hour from which these users were drawn was considered to be the average of those present in classes before and after the interval surveyed. For planning purposes it seems advantageous to use the peak or noon hourly load as the determinant of the number of fixtures. This noon peak occurs to some degree for all fixture types.

The average time interval required by users of urinals was 40 seconds. Therefore, if only one urinal was available, and if the 9.3 persons are rounded to 10, 400 seconds or six minutes and 40 seconds would be required to satisfy the fixture demand. If all the users had entered the toilet simultaneously, the waiting time would be six minutes for the last man to use the urinal. It is felt that this is excessive and that the student should find it possible to use a urinal in the ten-minute class break even though he is travelling between buildings to get to the next class. The average time required to leave a building of four stories or less or to enter such a building and proceed to a classroom is two minutes. Thus, if four minutes of the ten-minute break are spent in the buildings, six minutes remain. Three of these might be spent in inter-building travel of up to 700-800 feet, leaving three for miscellaneous activities such as using toilet facilities. If the student spends a little less than a minute at a urinal, then about two minutes is available for waiting time.

Admittedly this is entirely hypothetical. There is very little data on what proportion of students move between buildings at a given hour and what proportion remain in the building used during the preceding hour. Admittedly also, there is no "average" distance between buildings. Yet a case may be made for setting two minutes as a desirable limit of waiting time for urinals. Longer intervals will almost certainly provoke impatience and resentment.

A reasonable balance between convenience and economy of fixture cost may be said to be expressed in the following example, derived from the same field survey. Assume 15 users of urinals between classes out of a population of 150 men.[a] Assume that not more than eight arrive simultaneously. This is a higher proportion than was

[a]Urinals for women have been used occasionally, but with so little general acceptance that they have not been included in this survey.

[a]The proportion of 15 users from a population of 150 derives from rounding the 9.3/100 ratio noted at the noon hour peak.

TABLE 1 Classroom Buildings: Percentage of Male Population Using Urinals Between Classes

Survey Location	Survey Time Intervals	Number of Facility Users	Average Population[a]	Users as Percent of Population
Example A	8:50 – 9:00	3[b]	na	na
	9:50 – 10:00	14	161	8.7
	10:50 – 11:00	9	146	6.2
	11:50 – 12:00	17	115	14.8
Example B	8:50 – 9:00	5[b]	na	na
	9:50 – 10:00	18	199	9.0
	10:50 – 11:00	11	164	6.7
	11:50 – 12:00	12	155	7.7
Example C	8:55 – 9:05	2[b]	na	na
	9:55 – 10:05	5	116	4.3
	11:55 – 12:05	16	148	10.8
Examples A, B, C		102	1204	8.5
Examples A, B, C, 12 noon only		45	418	9.3

[a] "Average" refers to the average population of the classes immediately preceding and succeeding the ten minute interval listed.

[b] Excluded from total, as population for preceding hour was not recorded. It seems clear that the peak load does not occur at this time.

na — not available

observed in any of the surveyed toilets, where waiting time did not exceed one minute. If there are two urinals, two persons can proceed without waiting while six persons will wait for intervals of 40, 80, and 120 seconds. Thus the last two men to use the urinals will have waited two full minutes. If two urinals are satisfactory for a population of 150, then each urinal can serve 75 men.

However, as indicated in the preceding section of this study, the number of fixtures programmed must be related to station capacity rather than to actual population if the data is to be of use in planning. To translate the formula derived from field observation into a planning standard, the previously derived capacity utilization factor must be used. Therefore,

$$\frac{1}{75} \times 66\,2/3\% = \frac{1}{112.5}$$

Rounding this to a more convenient figure, we arrive at the formula that one urinal will serve 110 student stations.

2. Men's Water Closets

In water closet utilization the difference between average use and peak use is greater than was observed in the use of urinals, although peak use is again at noon in classroom buildings. The survey summarized in Table 2 indicates 2.6 users per 100 population at noon compared to an average of 1.7 for all morning hours. Again, using the noon figures seems justified if the toilets are to serve the needs of the student population.

As the average time required for water closet use was three minutes and twenty seconds, it is far less likely that a student would use this type of facility in intervals between classes when interbuilding traffic was involved. An acceptable waiting interval is considered to be equal to the time

for one incidence of use, slightly over three minutes. Thus each water closet can be considered to have a quota of two users during the ten-minute interval. To assume three users would be to assume a more continuous flow of traffic to the toilet room than is likely. If one minute elapsed between two instances of use, there would be no opportunity for a third user of the fixture unless he were to overstay the ten-minute class break.

If one hundred men produce 2.6 users, which may be rounded to 3.0, then we are safe in assuming that two hundred men will produce no more than 6.0 users at the noon peak. If two instances of use are assumed per fixture, three water closets will be required for an actual population of 200 or a station capacity of 300. Thus, one water closet will serve 100 men.

3. Men's Lavatories

Lavatories at the noon hour were used by 9.1 percent of the population surveyed, while the average percent of use for all morning hours was 7.6 percent. (See Table 3) Lavatory use at noon represented 76 percent of the sum of instances of use of urinals and water closets combined, while for all hours lavatory use was 75 percent of the sum of urinal and water closet use. This suggests that heavy fixture use in classroom buildings at noon is not so much prefatory to lunch as it is related to the length of time since the early morning peak, which must have occurred at the student's residence. Incidently, at all the institutions surveyed, classes were held from noon to 1 PM as well as from 11 AM to noon.

The duration of individual use of lavatories was observed to be 30 seconds. If one assumes that half (or five) of the noon hour users will appear simultaneously, then providing one lavatory will

TABLE 2 Classroom Buildings: Percentage of Male Population Using Water Closets Between Classes

Survey Location	Survey Time Intervals	Number of Facility Users	Average Population[a]	Users as Percent of Population
Example A	8:50 – 9:00	2[b]	na	na
	9:50 – 10:00	3	161	1.9
	10:50 – 11:00	1	146	0.7
	11:50 – 12:00	4	115	3.5
Example B	8:50 – 9:00	1[b]	na	na
	9:50 – 10:00	3	199	1.5
	10:50 – 11:00	1	164	0.6
	11:50 – 12:00	1	155	0.6
Example C	8:55 – 9:05	4[b]	na	na
	11:55 – 12:05	6	148	4.0
Examples A, B, C		19	1088	1.7
Examples A, B, C, 12 noon only		11	418	2.6

[a b] See Table 1 for footnotes.
na — not available

TABLE 3 **Classroom Buildings: Percentage of Male Population Using Lavoratories Between Classes**

Survey Location	Survey Time Intervals	Number of Facility Users	Average Population[a]	Users as Percent of Population
Example A	8:50 – 9:00	6[b]	na	na
	9:50 – 10:00	14	161	8.7
	10:50 – 11:00	8	146	5.5
	11:50 – 12:00	16	115	13.9
Example B	8:50 – 9:00	8[b]	na	na
	9:50 – 10:00	16	199	8.0
	10:50 – 11:00	7	164	4.3
	11:50 – 12:00	9	155	5.8
Example C	8:55 – 9:05	6[b]	na	
	11:55 – 12:05	18	148	
Examples A, B, C, all hours		88	1088	7.6
Examples A, B, C, 12 noon only		38	418	9.1

[a,b] See Table 1 for footnotes.
na — not available

results in two minutes of waiting time for the last user of this group. In practice the waiting time will probably be less, for lavatory use should be less discontinuous than the use of the other fixtures. For example, if a group of men entered a toilet room simultaneously and waited varying lengths of time to use a single urinal, after which each man used a lavatory, then the lavatory would be used in sequence, without waiting time. This is not exactly the case, because of the presence of users of water closets and perhaps of those who are only using the lavatory. However, these last two groups form only a minority, so that it appears that the two minute waiting time is an upper limit and that it is quite likely that the average waiting interval would be only one minute, if one lavatory were available to an actual population of 100.

Following the procedure used for other fixture types, this will produce a planning standard of one lavatory per 150 student stations.

4. Women's Water Closets

Water closets for women can be analyzed in a somewhat different way from the other fixtures discussed to this point. The difference is due to the range of duration of use, based on the different functions served by the same fixture type. A larger survey sample is needed to establish the average use time than is the case with urinals or water closets for men, but from the observations conducted as part of this survey, it appears that this average is about 1.8 minutes. A majority of instances of use are about 1.1 minutes duration, while the balance average about three minutes.

Using the peak load percentages for the noon hour, the following example is offered as a basis for deriving the number of water closets in rela-

tion to female population.

Assume 20 users out of a population of 200, and assume further that no more than 12 will arrive at the toilet simultaneously. If five water closets are available, then five of the twelve can be accomodated immediately. Three of these five water closets will be used for only 1.1 minutes each, while two will be used for about three minutes each. Thus, the remaining seven users will wait from 1.1 to 2.2 minutes for three of the fixtures and for about three minutes for the other two fixtures. The average waiting time for all seven will be very close to two minutes, or about the same interval previously considered as a desirable upper limit for men's urinals. Thus, five water closets will serve 200 women, a ratio of 1:40. Converting as before to student capacity, the recommendation is a fixture-student ratio of 1:60.

5. Women's Lavatories

Lavatories in men's rooms are used almost exclusively for washing the hands, although there is a small percentage of time spent at these fixtures for combing the hair, because of the presence of mirrors behind the lavatories. In ladies' toilets the time spent in attention to the hair and to cosmetics is much greater, so that it is desirable to assign these functions to an area independent of the lavatories, served by a mirror and shelf. The reasons for this are clear: mirrors and shelves, relatively inexpensive items, will permit a reduction of time spent at the lavatory, which in turn means fewer plumbing fixtures. Furthermore, hair frequently clogs up lavatory drains.

In the women's toilet rooms surveyed in classroom buildings there was no separate mirror wall, so that it was necessary to deduct those users of lavatories who were concerned only with the

TABLE 4 Classroom Buildings: Percentage of Female Population Using Water Closets Between Classes

Survey Location	Survey Time Intervals	Number of Facility Users	Average Population[a]	Users as Percent of Population
Example D	8:55 – 9:05	1[b]	na	na
	11:55 – 12:05	4	63	6.5
Example E	8:55 – 9:05	6[b]	na	na
	9:55 – 10:05	7	91	7.7
	10:55 – 11:05	6	84	7.1
	11:55 – 12:05	10	79	12.7
Examples D, E		27	317	8.5
Examples D, E, 12 noon only		14	142	9.9

[a][b] See Table 1 for footnotes.

na — not available

TABLE 5 Classroom Buildings: Percentage of Female Population Using Lavatories Between Classes

Survey Location	Survey Time Intervals	Number of Facility Users	Average Population[a]	Users as Percent of Population
Example D	8:55 – 9:05	1[b]	na	na
	11:55 – 12:05	5	63	8.0
Example E	8:55 – 9:05	4[b]	na	na
	9:55 – 10:05	5	91	5.5
	10:55 – 11:05	6	84	7.2
	11:55 – 12:05	9	79	11.4
Examples D, E		25	317	7.9
Examples D, E, 12 noon only		14	142	9.9

[a,b] See Table 1 for footnotes.

na — not available

mirror and did not use water. Therefore, the recommended fixtures: student ratio for lavatories is contingent on the presence of a mirror and shelf on a different wall from the lavatories.

The survey figures, approximately 10 users per hundred population, are similar to the utilization prevailing in the men's lavatories. However, the duration of use was 40 seconds rather than thirty. If one assumes a maximum allowable waiting time of two minutes, then the fixture: population ratio can be derived from the following example.

Assume fifteen users, eight of whom will arrive simultaneously, out of a population of 150 women. If two lavatories are available then the maximum waiting time at each fixture will be three times forty or one hundred and twenty seconds (two minutes). Thus one lavatory for seventy-five women (actual population) is sufficient. As a planning standard the ratio may be expressed as 1:110.

B. Teaching Laboratories

There is no reason to presume that teaching laboratory areas should have greater or fewer numbers of fixtures in relation to stations than is required for classrooms. However, it may be well to be alert to two circumstances peculiar to laboratories. First, students' hands need much more cleaning during and after laboratory work. If the sinks for this purpose are in the laboratory itself, the load on toilet room lavatories may be reduced. If not, the reverse will be true. Secondly, the student in a two or three hour laboratory session is more likely to leave the room during the session than he is if attending a lecture. The net result of this is to distribute the use over a longer period, reducing the peak load. This reduction in load is

difficult to quantify, however, in view of the fact that the student arriving at a laboratory building or floor from elsewhere may use the toilet near the laboratory. Thus, there seems to be no choice but to use the classroom standards for teaching laboratories as well.

C. Other Building Types

Remaining for consideration is office and research space in college buildings. These house a more nearly fixed population through the greater part of the working day than do classroom buildings. The distribution of peak loads on toilet facilities is related to that of a commercial office building, except that the arrival of persons at the beginning of the day and their exit at the end of the day is not nearly so concentrated. In the survey samples the peak load was just before the lunch hour.

Toilets in office and research areas receive much heavier use in proportion to population than those in classroom buildings. Whereas the student may use a variety of toilet locations between 9 AM and 5 PM, the office worker or researcher usually has convenient access only to the one nearest to his work station. It is also fairly common for some office workers, graduate students and other staff members to eat lunch in the buildings where they work, again serving to concentrate toilet room activity.

Two large, post-World War II research buildings were surveyed. A floor in one building, to be called Example F, had a population on the morning of the survey of 39 men and 43 women. The men's toilet consisted of four lavatories, three urinals and three water closets. The peak load on lavatories and urinals was between 12:00 noon and 12:30 PM, when there were seven instances of lavatory use and six of urinal use. The peak period for water closets was between 11:00 AM and 11:30 AM, when there were three users. However, the significant point is that the distribution of use time was such that for each fixture type one unit would have served, if minimal waiting time is allowable. Specifically, only one man entered to find a lavatory in use and only one entered to find a urinal or a water closet in use. The survey form data may be condensed to show this information combined for all the peak periods:

	Urinals			Water Closets			Lavatories			
No. Used Simultaneously:	1	2	3	1	2	3	1	2	3	4
Frequency of Use:	5	1	0	2	1	0	6	1	0	0

This indicates that one of the lavatories was used six times, that two were used simultaneously on only one occasion and that no more than two were used simultaneously at any one hour. Thus, if the single user in the "2" column waited for the desired fixture to be vacant, then a ratio of 1:39 for all fixture types would serve this group of men during peak load periods.

In Example G, at another institution, where the building surveyed was in a very different relation to the campus than was the case of Example F, the data were remarkably similar. The population consisted of 44 men and 25 women. The men's toilet comprised two urinals, three water closets and three lavatories. The half-hour periods of heaviest activity showed the following pattern:

	Urinals		Water Closets			Lavatories		
No. Used Simultaneously:	1	2	1	2	3	1	2	3
Frequency of Use:	6	1	3	1	0	7	1	0

Thus, as in example F, if there had been only one fixture of each type, then one individual would have had to wait 40 seconds to use the urinal, a second man would have waited about three minutes to use the water closet and a third man would have waited one-half minute to use the lavatory. These waiting intervals occurred only once for each fixture type from 8:45 AM to 12:45 PM. If this is not considered too burdensome, then a ratio of one of each of the three fixtures to 40 occupants appears reasonable.

For the 43 women in Example F there were three lavatories and three water closets, plus a long mirror on a wall opposite from the lavatories. Here the peak load for all fixtures was between 11:00 AM and 11:30 AM. The pattern of use at that time is hown below.

	Water Closets			Lavatories		
No. Used Simultaneously:	1	2	3	1	2	3
Frequency of Use:	4	3	2	6	4	0

It is obvious that at least two water closets are required, because of the frequency of simultaneous use. However, no more than two are required if a waiting interval for each of two women of from one to three minutes is acceptable. In that case the fixture: population ratio would be 1:21.5. For the lavatories a case might be made for supplying only one, resulting in a waiting period which could vary from a minimum of one-half minute to a maximum of four minutes. Nevertheless, one might properly consider a ratio of 1:43 somewhat scant.

In Example G the 25 women had available two water closets, two lavatories and a separate mirror. There were two identical peak periods, from 11:00 AM to 11:30 AM and from 12:00 noon to 12:30 PM. Both can be expressed as follows.

	Water Closets		Lavatories	
No. Used Simultaneously:	1	2	1	2
Frequency of Use:	3	1	3	1

This example could be interpreted as justifying a ratio of 1:28 for each fixture type.

Because of the very limited size of the sample in these office and research areas it is probably best to be conservative. On balance a ratio of 1:20 is recommended for water closets for women and 1:40 for men. For men's urinals also 1:40 seems reasonable. However, it is felt that the samples did not adequately test lavatory utilization. As this is to a considerable extent a function of the use of the other fixture types, it is suggested that for women the ratio of lavatories to water closets be consistent with findings for classroom areas. Therefore,

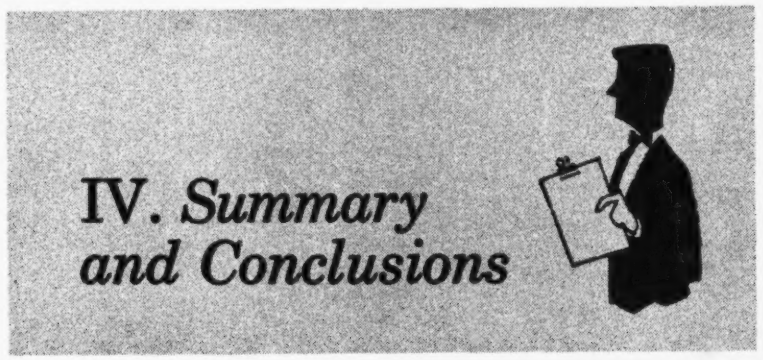
$$\frac{1:x}{1:20} = \frac{1:110}{1:60},$$

where x = the number of lavatories in non-classroom buildings, 1:20 = the ratio of water closets to occupants in non-classroom buildings, 1:110 = the ratio of lavatories to occupants in classroom buildings and 1:60 = the ratio of water closets to occupants in classroom buildings. Thus, x = 37, which for reasons of convenience and caution may be lowered to 35. Rceommended, then, is a ratio of 1:35 for women's lavatories.

For men's lavatories in office and research areas it is believed that a ratio of 1:50 is proper. The discrepancy between men's and women's requirements is explained by two points: 1) a higher percentage of women entering toilet rooms use lavatories; 2) the duration of use is one-third longer than it is for men.

In applying these recommended standards to design problems, a corollary should be offered where the numbers of personnel of any sex require an installation of less than two fixtures of each type. In rooms with only one fixture of a kind the deviation from the average waiting time can be a source of difficulty. A large number of small toilet rooms are also inefficient from a maintenance standpoint.

Therefore, it is recommended that, where possible, a minimum of two fixtures of each type be installed. If the population of the floor does not justify this number of fixtures, then men's and women's toilets should be located above each other on alternate floors.



IV. *Summary and Conclusions*

The recommendations of this study are summarized in Tables 6 and 7, which also present condensed information on fixture requirements in a number of building codes. It may be seen that, although the codes vary from one another, they call for more fixtures per person in almost all cases than are considered necessary, according to this report.

Nevertheless, it is felt that the report is conservative in its conclusions and that the probable effect of additional sampling would be to support still lower ratios. The surveys actually made tend to justify the recommended fixture : occupant ratios as permissible but not necessarily as minimal, consistent with reasonable standards of comfort, convenience and sanitation.

In order to evaluate the significance of these findings the cost of toilet rooms and plumbing fixtures must be investigated. Let us assume a four story classroom building with a men's room on each floor, one above the other. The average space in the building may be worth thirty dollars per square foot. However, to estimate the cost of the toilet rooms we must add to this figure the cost of floor and wall tile, toilet stalls, hung ceiling, piping, plumbing fixtures and accessories. For a room of 230 square feet, with three water closets, three urinals, and three lavatories these items will cost approximately eight thousand dollars.[a] Thus the total value of the room may be thought of as $12,600.

If it is possible to serve the same population with two water closets, two urinals and two lavatories, then the toilet room need only be 150 square feet. The value of the basic room becomes four thousand five hundred dollars and the materials, labor and equipment that transform it to a toilet will be worth $4,300, for a total of $8,800. Thus omitting one of each type of fixture results in a saving of about $3,800, exclusive of maintenance and other annual costs. In four such rooms the savings in construction cost would thus be $15,200.

Where the total number of fixtures is constant, for each case in which a urinal is substituted for a water closet the saving will be approximately $425 in materials, labor and equipment plus perhaps $375 in basic space.

[a] This estimate is based on high quality materials and equipment in an Eastern United States location.

TABLE 6

Plumbing Fixture Requirements: Comparison of Recommended Practice with Selected Building Code Specifications for Classroom Occupancy

	Fixture Type	Recommended	Code				
			Indiana[a]	National Plumbing Code[b]	New York City[c]	Ohio[d]	Wisconsin[e]
			(Occupants of Building Per Fixture)				
Male	Urinals	110	75	30	--[f]	50	30
	Water Closets	100	100	100	40[f]	100	60
	Lavoratories	150	100	100	--[g]	100	60
Female	Water Closets	60	50	45	40	45	30
	Lavoratories	100	100	100	--[g]	100	60

[a]Indiana ratios are specifically for "college and university instructional rooms".

[b]This code is prepared jointly by the American Public Health Association and the American Society of Mechanical Engineers. The fixture ratios are for secondary schools, none being offered for college facilities.

[c]New York City ratios are for all "schools", including colleges.

[d]Ohio ratios are for "advanced" schools, including colleges.

[e]Wisconsin ratios are for "schools, universities, academies", etc.

[f]This code requires one "toilet fixture" for 40 pupils; for males at least one-quarter of this number must be water closets. This is the equivalent of a ratio of 3:160 for urinals and 1:160 for water closets.

[g]This code does not specify a ratio of occupants per lavatory.

TABLE 7 Plumbing Fixture Requirements: Comparison of Recommended Practice with Selected Building Code Specifications for Office Occupancy

	Fixture Type	Recommended	Code				
			Indiana	National Plumbing Code	New York City	Ohio	Wisconsin
			(Occupants of Building Per Fixture)				
Male	Urinals	40	--[a]	--[a]	--[a]	--[a]	40
	Water Closets	40	10-30[b]	15-40[d]	15-30[f]	15-40[d]	20
	Lavoratories	50	10-15[c]	15-45[e]	--[g]	15-45[e]	--[h]
Female	Water Closets	20	10-30[b]	15-40[d]	15-30[f]	15-40[d]	20
	Lavoratories	35	10-15[c]	15-45[e]	--[g]	15-45[e]	100[h]

[a]Urinals may be substituted for one-third of the required number of water closets.

[b]For number of occupants from 1-100 the ratio changes from 1:10 to 1:20. For additional occupants over 100 a ratio of 1:30 is specified.

[c]A ratio of 1:10 is specified for the first 100 occupants, 1:15 thereafter.

[d]For numbers of occupants from 1-150 the ratio changes from 1:15 to 1:25. For additional occupants over 150 a ratio of 1:40 is specified.

[e]For numbers of occupants from 1-125 the ratio changes from 1:15 to 1:25. For additional occupants over 125 a ratio of 1:45 is specified.

[f]For numbers of occupants from 1-190 the ratio changes from 1:15 to 1:27.14. For additional occupants over 190 a ratio of 1:30 is specified.

[g]This code does not specify a ratio of occupants per lavatory.

[h]This code requires a minimum of one lavatory for five water closets or for men, five water closets and urinals combined; however, it recommends one lavatory for 2-3 such other facilities.

Appendix

The field survey data was recorded in the form reproduced here as Exhibit 2. The instruction sheet for the use of survey personnel is included as Exhibit 1.

One person is needed for each toilet room to be surveyed, plus one additional person to count the population at each hour. More complete data on duration of use would be available if two persons were stationed in the room, but it was felt that this would give too much prominence to the survey activities, with possible distortion of the normal pattern. The survey as actually conducted was not considered to be an inhibiting factor.

EXHIBIT 1

INSTRUCTION SHEET FOR SURVEY OF TOILETS

1. Record the population on the floor or floors using the toilet room under observation. Record the number of men and women separately. (In classroom areas record the population at each hour.)

2. Note the number of fixtures of each type in the room and eliminate by cross natching those columns on the Field Data Sheet representing fixtures in excess of those actually installed in the toilet room under observation. Do not cross hatch the "W" column.

3. Each instance of fixture use should be recorded by placing a vertical mark ("1") opposite the proper time interval in the proper column.

4. If only one fixture is in use at a particular time, mark all "1"s in the first column for that fixture type, regardless of which fixture is actually used. If two fixtures are in use simultaneously, mark the "1" in each of the first two columns, and so forth.

5. If all fixtures are in use and one or more persons are waiting, mark one or more "1"s in the "W" column. When the persons waiting gain access to the fixture, mark "1" in the appropriate fixture column.

EXHIBIT 2

Field Data Sheet – Circulation Facilities

Frequency of Use

Time[b]	Lavatory						Urinal						Water Closet					
	1	2	3	4	5	W[a]	1	2	3	4	5	W[a]	1	2	3	4	5	W[a]
8:30-9:00																		
9:00-9:30																		
9:30-10:00																		
10:00-10:30																		
10:30-11:00																		
11:00-11:30																		
11:30-12:00																		
12:00-12:30																		
Total																		

Institution:

Date:

Building:

By:

Floor:

Room No.:

W[a] = number of persons waiting.

[b]For classroom areas this column read "9:00-9:10, 9:10-10:00, 10:00-10:10....." or similarly, depending on the actual schedule of classes.

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